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Heavy flavour production in the semi-muonic channel in pp and Pb–Pb collisions measured with the ALICE experiment

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The inclusive production differential cross section of muons from heavy flavour decays measured with the ALICE experiment is presented. In pp collisions at $\sqrt{s} = 7$ TeV, the heavy flavour muon production cross section, measured at forward rapidity ($2.5 < \eta < 4$), is compared to perturbative QCD predictions. A good agreement is found between the data and the model calculations. In Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV the ratio of inclusive muon yield in central to peripheral collisions (R_{CP}) as a function of the collision centrality is reported. A suppression of the inclusive muon yield is observed.

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1. Introduction

The properties of the high-density medium formed in heavy-ion collisions at LHC can be investigated through heavy-quark production [1]. Heavy quarks are created in the initial hard collision processes with short formation time and are expected to lose energy while passing through the high-density strongly-interacting medium [2]. Measurement of open heavy flavours is expected to bring information on the density of the medium. It is predicted that heavy quarks lose less energy than light particles in the medium [3]. This phenomenon, called “dead cone effect”, has not yet been observed in heavy ion collisions. A complete understanding of heavy flavour production mechanisms in heavy-ion collisions requires the study of their production in proton-proton collisions. Moreover, the study of open heavy flavour production on pp collisions is of crucial interest as an important test of perturbative QCD (pQCD) calculations in a new energy regime.

ALICE (A Large Ion Collider Experiment) [4] is the LHC (Large Hadron Collider) experiment dedicated to the study of heavy ion collisions and its main purpose is to investigate the properties of deconfined nuclear matter.

Since 2010, ALICE has successfully collected pp data at $\sqrt{s} = 2.76$ TeV and $\sqrt{s} = 7$ TeV and Pb-Pb data at $\sqrt{s_{NN}} = 2.76$ TeV.

The results on the production of single muons from heavy flavour decays at forward pseudo-rapidity ($2.5 < \eta < 4$) in pp collisions at $\sqrt{s} = 7$ TeV and its comparison to model predictions is presented. A measurement of the ratio of inclusive muon yield in central to peripheral collisions, normalized by the number of nucleon-nucleon collisions (R_{CP}), in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV is also discussed.

2. Results in pp collisions at $\sqrt{s} = 7$ TeV

The muon spectrometer [4] covers the pseudo-rapidity range $-4 < \eta < -2.5$ and allows to detect muons with momentum larger than 4 GeV/c. It is composed of a passive front absorber, a beam shield, a 3 T-m dipole magnet, five stations of high granularity tracking chambers and two stations of trigger chambers behind a 1.2 m thick iron wall.

The single muon analysis is based on a data sample corresponding to $L_{int} = 16.5 \text{ nb}^{-1}$. Details on the analysis procedure can be found in [5, 6]. The pp data samples consists of minimum bias trigger events (MB) and muon trigger events (m-MB), the latter requiring in addition to a MB event, the presence of one muon above a p_t threshold of about 0.5 GeV/c that reaches the trigger system. After event and track selection cuts, the main background source consists of muons coming from light hadron decay (pions and kaons, mainly) which corresponds to 25% of the statistics for muons with $p_t > 2$ GeV/c. The background is determined by means of simulations using PYTHIA [7] (tune Perugia-0 [8]) and PHOJET [9]. The detector response is simulated using GEANT3 [10]. Details on the background subtraction can be found in [5]. The total systematic uncertainty varies from about 13% ($p_t = 2$ GeV/c) to 10% ($p_t = 10$ GeV/c) and is dominated by the systematic uncertainty on the background subtraction. Within the applied particle selection, a reconstruction efficiency of about 90% is found for muons with $p_t > 2$ GeV/c and $2.5 < \eta < 4$.

Preliminary measurement on the production differential cross section of muons from charm and beauty decay as a function of p_t and as a function of η in the p_t range 2-10 GeV/c, is shown in Fig. 1. Error bars and boxes correspond to statistical and systematic uncertainties, respectively. The systematic uncertainty on the pp minimum bias cross section is not displayed. The ratios between data and Fixed-Order Next-to-Leading Log (FONLL) predictions [11] are shown on the bottom panels of Fig. 1. A good agreement between data and model predictions is observed within errors, for both p_t and η distributions and one can also notice that the data lie in the upper limit of the model calculations.

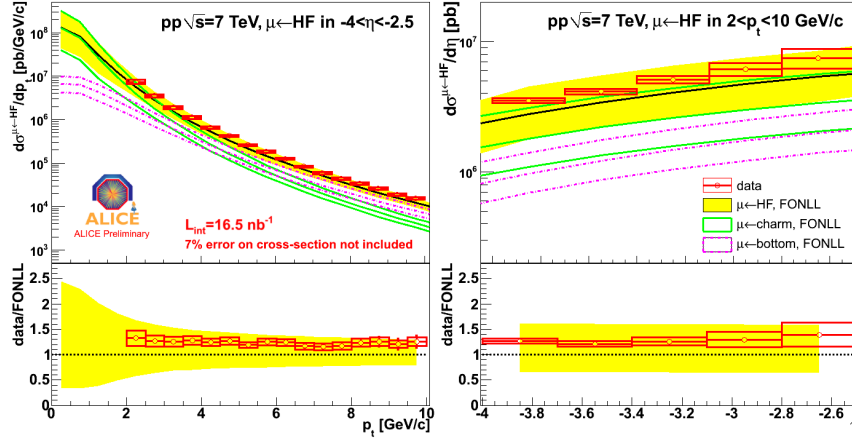


Fig. 1. Inclusive production p_t -differential (left) and η -differential (right) cross section of muons from heavy flavour decay.

3. Results in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV

The analysis is based on about $20 \cdot 10^6$ minimum bias collisions which passed the analysis quality selections. The corresponding integrated luminosity is $L_{\text{int}} = 2.5 \mu\text{b}^{-1}$. Events are selected according to their degree of centrality by means of the VZERO (large η scintillator hodoscopes) [12] amplitude which is fitted using the Glauber model [13] to determine intervals corresponding to percentages of the nuclear cross section. Figure 2 presents the VZERO amplitude distribution. Several centrality classes can be selected from the most peripheral collisions (80-90%) up to the most central ones (0-5%).

The analysis strategy is similar to the one described for pp collisions at $\sqrt{s} = 7$ TeV and it is also discussed in [5, 6]. The data were corrected for acceptance \times efficiency. The centrality dependence of the tracking efficiency, smaller than 2%, is neglected. The fraction of muons from light hadron decays is presently not subtracted from the data: its contribution was estimated by means of a minimum bias simulation based on the HIJING [14] event generator (without quenching) and amounts to 6-15% (2-9%) for $p_t > 4$ GeV/c ($p_t > 6$ GeV/c), for peripheral-central collisions.

The ratio of inclusive muons in central to peripheral collisions (R_{CP}) is determined according to:

$$R_{\text{CP}}(p_t) = \frac{[1/\langle T_{\text{AA}} \rangle \times dN/dp_t]_{\text{central}}}{[1/\langle T_{\text{AA}} \rangle \times dN/dp_t]_{\text{peripheral}(60-80\%)}}. \quad (1)$$

$\langle T_{\text{AA}} \rangle$ is the nuclear overlap function and dN/dp_t the muon p_t distribution.

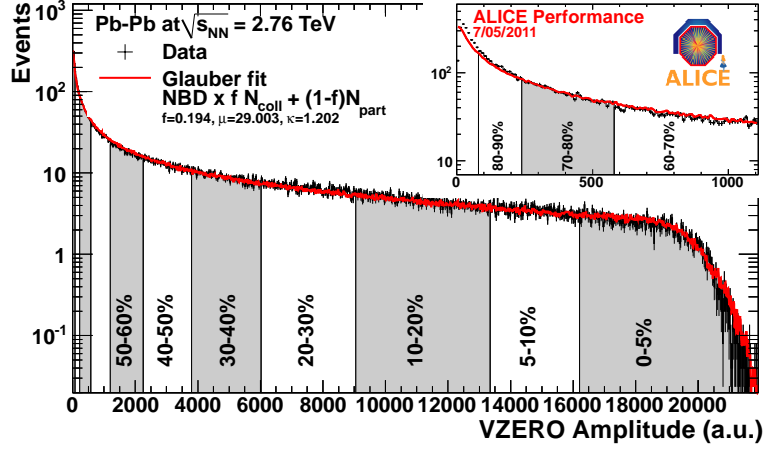


Fig. 2. Multiplicity distribution of the VZERO detector fitted with the Glauber model [13].

Figure 3 presents the inclusive muon R_{CP} as a function of the collision centrality. In order to minimize the background contamination, muons with

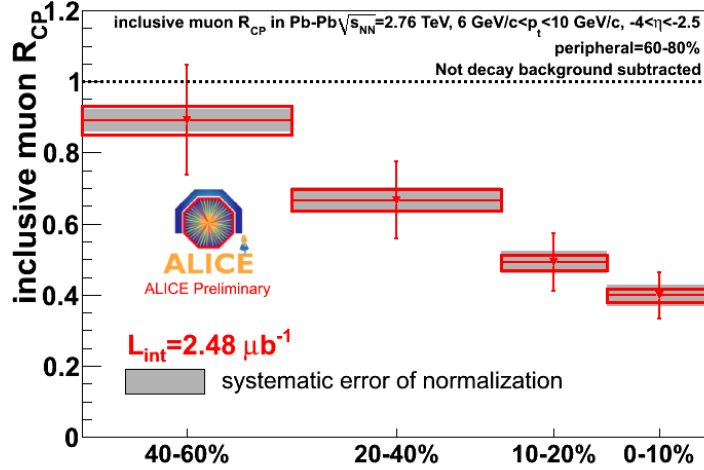


Fig. 3. Inclusive muon R_{CP} as a function of the centrality.

a $p_t > 6$ GeV/ c are selected. A suppression of the muon production is observed and it increases with the centrality. This can be interpreted as a signature of a dense medium formed in central collisions as the energy loss

of heavy quarks is expected to increase with the collision centrality. The observed R_{CP} suppression is qualitatively in agreement with the suppression of electron yield from heavy flavour decays measured at mid-rapidity with ALICE [15].

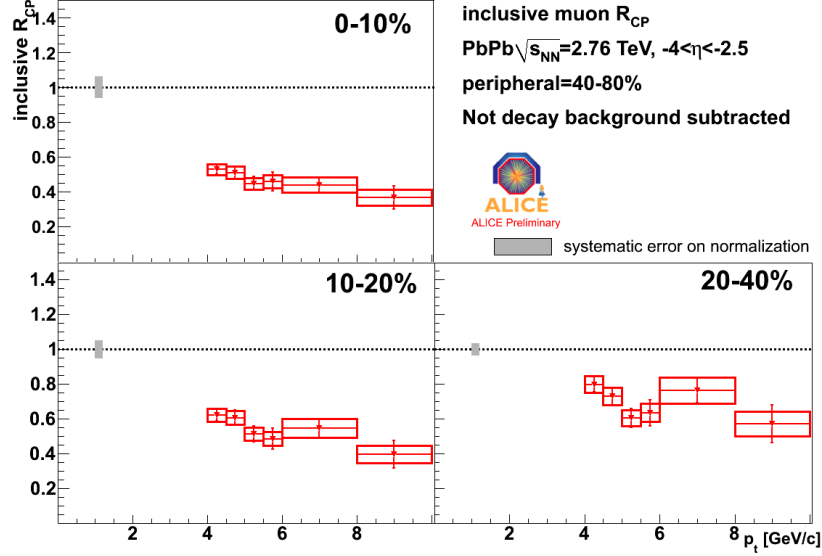


Fig. 4. Inclusive muon R_{CP} as a function of p_t for three collisions centralities.

Figure 4 presents the inclusive muon R_{CP} as a function of p_t for different collision centralities. The observed suppression of the muon yield in different centrality classes does not show any significant p_t dependence within the errors of the measurement. This result is also compatible with the p_t dependence of the nuclear modification factor (R_{AA}) of electrons measured at mid-rapidity [15].

4. Conclusions

The differential production cross section of muons from heavy flavour decays at forward rapidity, for $2 < p_t < 10$ GeV/c, in pp collisions at $\sqrt{s} = 7$ TeV has been measured using the ALICE muon spectrometer. A good agreement is found between the data and FONLL predictions. A suppression of the inclusive muons yield is observed in Pb-Pb collisions and it increases with centrality. This suppression shows no significant p_t dependence for $p_t > 4$ GeV/c.

The 2011 LHC Pb-Pb run will provide higher statistics which will allow to measure with a better accuracy the p_t dependence of the nuclear mod-

ification factor R_{CP} and bring new insights on the modification of heavy flavour production in the hot and dense nuclear medium.

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